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ORGANIZATION OF METEOROLOGICAL AND HYDROLOGICAL SERVICES

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ORGANIZATION OF METEOROLOGICAL AND HYDROLOGICAL SERVICES

(Prepared on behalf of WMO by Mr. Max A. Kohler,
President of the WMO Commission for Hydrological Meteorology)

1. Introduction

The successes achieved in the field of hydrology and meteorology provide with possibility to use the knowledge in these fields to the great benefit of national economy. This is particularly true with respect to the development and utilization of water resources in less developed countries where this problem could be solved on scientific and planned lines from the very outset. It is impossible of course to give in one or even several papers a comprehensive outline of the application of hydrology and meteorology to the water economy and flood control problems. There is no attempt therefore to do so in the paper. Moreover, this paper is based on the assumption that importance of hydrological and meteorological services in solution of problems is fully recognized. Only some organizational aspects of hydrological and meteorological services are considered below, and the main of them are the imperative need for close coordination between the two services and the importance of an adequate, stable basic data programme.

Hydrological and meteorological services required for water development and management

2. Although the hydrometeorological factors involved are much the same, there are important differences in the requirements for planning and designing of water development projects as compared to those for managing (operating) completed facilities. Design problems are of a nonrepetitive nature; they could, in many cases, be solved directly from streamflow and storage data if sufficient observations were available; there is no necessity to determine the time sequence of future hydrological events; and the solution to the problem need not be geared to a rigid time schedule. In contrast, water management problems are of a continuing nature; their solution requires forecasts of subsequent streamflow (in time sequence) and heavy reliance on related hydrometeorological factors; and hydrological analysis of the current situation must be completed in a minimum of time. Thus the relationships between hydrological and meteorological events must be utilized to extend the time range of streamflow predictions for management purposes, while in the design phase need for utilizing such relationships arises largely from the fact that it is not economically feasible to obtain long-term records of discharge at every possible site of future development.

Basic Data Requirements

3. The development of forecasting procedures and the design of water control and utilization structures require that the same data be readily available for long periods of time. To meet these needs, the data should be processed and published on a routine basis. All three functions (collection, processing and publication) customarily fall within the jurisdiction of the service organizations.

4. Although it is not necessary to make a steadfast distinction between hydrological and meteorological elements when considering the needs, it cannot be avoided in a discussion of organizational patterns. For example, is the measurement of precipitation the function of a hydrological service or a meteorological service ? While precipitation constitutes a phase of the hydrological cycle, it is at the same time a weather phenomenon. Without further belaboring the problem of classification, the principal data to be provided by the hydrological and meteorological services are enumerated below. (1, 2)

(i) Discharge and stage data are truly hydrological in nature and they are basic to the solution to most design and operation problem. Since streamflow data are derived from continuous records of stage and occasional discharge measurements, the two types of data are inseparable and should obviously be collected and published by the same agency. Similarly lake, or reservoir, levels are used to derive changes in storage - a basic factor in water budget of a basin. Synoptic reports of stage and discharge are required in the preparation of river forecasts.

(ii) The water level in unpumped wells is indicative of groundwater storage and variations in level are closely related to the discharge of perennial streams during rainless periods. Groundwater levels therefore assist in evaluating the hydrologic cycle of an area and are required for the design of irrigation and other water supply projects relying on subsurface supplies. Pumping tests and other discharge data also assist in the evaluation of the safe yield from a groundwater aquifer.

(iii) Thickness and other physical characteristics of river and lake ice are pertinent factors in the design of many hydraulic structures, in predicting ice breakup and consequent jams, and in planning navigation operations.

(iv) Among other things the economic feasibility of a reservoir depends upon the rate at which its capacity will be reduced through sedimentation. This aspect of design requires that observations be made of the suspended and bedload material in flowing streams and of the volumes of sediment deposited in lakes and reservoirs.

(v) Domestic, irrigation and industrial water supplies must meet certain standards of quality (including water temperature in some cases). Observations are needed not only to assure proper design, but also on a continuing basis for operational purposes.

(vi) The estimation of evaporation losses constitutes an important phase of reservoir design, particularly in arid and semiarid regions. Evapotranspiration (or consumptive use), when considered in conjunction with anticipated precipitation, is a measure of the water-supply requirements for irrigation projects. Although estimates can be derived from observations of related meteorological factors, evaporimeter measurements are invaluable.

(vii) Rainfall, snowfall and snow pack observations are indispensable to water development and utilization. Such data are used to bolster inadequate streamflow records and they are used operationally to forecast stage, discharge and water supply.

(viii) From a theoretical point of view, radiation is the controlling factor in the evapotranspiration and snowmelt processes. Wind, air temperature and humidity also affect the heat balance and measurements of these factors are therefore important in an evaluation of the hydrological cycle.

(ix) There are numerous other types of data which have value in solving water development and utilization problems but which are normally not made on a continuous basis over established networks. These include infiltration, percolation, soil moisture, flood damages, frost penetration, soil temperature and interception.

5. Much has been written concerning the planning of hydrological and meteorological networks for the collection of basic data. (1, 4) Although differences of opinion exist in some aspects of the problem, there is general agreement that the networks for the various pertinent elements should not be planned on an independent basis. Since a number of precipitation stations can be operated for the same cost as a single stream discharge station, Langbein recommends a ratio of about ten precipitation stations to one discharge station in newly established networks with the ratio dropping to five or six in later years. It is interesting to note that through independent planning of the two types of networks (and possibly other causes as well) the ratio of precipitation to discharge stations varies among the countries from as low as two to as high as forty. Perhaps more important than the over-all ratio of the two types of stations is the necessity to locate the stations so that the rainfall pattern can be delinated over each gauged headwater and tributary area.

6. It is most important that basic data be reliable, consistent and continuous. To assure that this is the case the field installations must be inspected and serviced at regular intervals - an expensive though necessary aspect of network operation. It is obvious that integrated operation of the various types of networks will minimize this cost and also that of paid observers when one observer can be utilized for making the several types of observations required.

7. The processing of data for publication frequently requires comparative analysis of hydrological and meteorological data. The estimation of stream discharge during periods of missing gauge-height record is often based on reported rainfall and related meteorological data. Hydrologic observations are commonly utilized in conjunction with climatological data and, therefore, integrated planning of publication format, card files, etc., can affect appreciable saving of analyst time.

Generalized Analyses and Specific Design Studies

8. Generally speaking, studies pertaining to the design of specific water resources projects are considered to fall outside the activities of the hydrological and meteorological services. On the other hand, there are many types of analyses which provide results of general applicability and which

can perhaps best be undertaken by the hydrological and meteorological services. Standard statistical analyses (means, extremes, frequencies, etc.) of observed factors fall within the latter category and perhaps also generalized maps of the water balance (runoff, precipitation, evaporation, evapotranspiration, etc.)

9. The solution to many problems in the areas of agriculture, water resources, etc., hinge upon a water-balance analysis, day-by-day, or month-by-month. Except where network density is unusually high, water-balance analysis requires thorough integration of hydrological and meteorological knowledge, and the same can be said for many aspects of hydrological research. Data requirements for research can be met, in many cases, by simply augmenting the general networks in selected small catchments. It is likely that the meteorological and hydrological services can meet the needs for such data at the least over-all cost.

Forecast Services

10. Hydrological forecasts serve a multitude of purposes by providing an improved basis for operational decisions. They are indispensable in the efficient control and utilization of water. Thus, a farmer will plant less acreage if a seasonal shortage of irrigation water is expected; a forecast of ice formation will permit appropriate decisions by navigation interests; and the prediction of a serious flood will signal a host of actions - evacuation of areas of inundation, elevation of moveable property, sandbaggings of levees, closing of flood gates, operation of flood-control dams, and rerouting of rail and highway traffic.

11. The short-range prediction of lake levels, river levels and stream discharge undoubtedly constitute the most important type of hydrological forecasting. With increasing emphasis on multiple-purpose projects and regional development of water resources, the need for river forecasts is multiplied and a reliable forecast service becomes economically invaluable. Seasonal and annual forecast of runoff volume also contribute to efficient operation of water resources projects in those areas where much of the flow is derived from winter snowfall.

12. Several other types of hydrological forecasts are of value in specific aspects of water management. In higher latitudes, the coming of winter halts navigation on rivers and lakes until the ice is once again dissipated by warm spring weather. The dates of opening and closing vary widely from year to year and their prediction assists in scheduling navigation and other operations. Storm surge forecasts on lakes and seacoasts and forecasts of seiches on lakes are also pertinent to efficient water management under some circumstances.

13. Once heavy rain or snowmelt has resulted in the formation of an isolated flood wave moving down the channel of a major stream, flood-routine techniques can be used to predict the downstream hydrograph, provided the wave is not augmented by subsequent rainfall over the intervening tributary area. To adequately account for local inflow, to permit predictions on small headwater streams, and to extend the time-range of forecasts, the predicted hydrograph must be derived from rainfall observations and forecasts in addition to

reported river stages. When snow cover is present, the snowmelt contribution to stream flow must also be estimated from reports of air temperature, humidity, wind speed and cloud cover. It is thus seen that both meteorological and hydrological reports are required in the preparation of river forecasts. The weather service traditionally and necessarily has an extensive national communications system for the collection of reports and considerable economies can be effected by utilizing this facility in rendering a river forecast service.

14. A rather new facility for maintaining an up-to-the-minute picture of meteorological conditions over a basin, radar is considered to have great potentiality in the improvement of water resources management. Since the equipment is extremely expensive it is not economically feasible for the hydrological and meteorological services to operate independent networks.

15. As is pointed out above, the river forecaster must have ready access to weather forecasts. His requirements cannot be met by generalized weather forecasts but must be tailored to fit the hydrologic situation existing in the area. Thus only the closest of coordinated efforts between the meteorologist and the hydrologist will lead to efficient water manegement.

Training of personnel

16. The organization of an adequate hydrological and meteorological (or hydrometeorological) service requires the provision of a number of specially trained personnel of both disciplines. This staff may be divided into three groups :

(i) hydrologists and meteorologists qualified at the university level;

(ii) technicians;

(iii) observers and equivalent staff.

Perfect results in training of personnel, including specialists of the first group, could be achieved by setting up institutes and technical schools of a special type, as is being done in some developed countries. For most of the relatively small countries however this will hardly be practicable or advisable with respect to the first group of specialists. The solution could be found in this case by arranging for special courses in the physics and geography departments of universities or at technical and agricultural institutes. The curricula of these courses could with the assistance of WMO be adopted from those followed in the developed countries. The sending of fellows to train in developed countries could also do much to help.

In the case of the second and third groups mentioned above, the training of local personnel should be adopted as a principal aim. For this purpose the setting up of special technical schools on a permanent basis and of special courses on a temporary basis could be recommended.

17. It should be mentioned that, as is made clear from the discussion in foregoing sections, the work of hydrologists and meteorologists ought to be closely linked. Moreover hydrologists using meteorological data and forecasts should be well familiar with meteorology. On the other hand meteorologists providing hydrologists with meteorological data and in particular with forecasts, must know and clearly understand the nature of hydrological requirements. There is thus a need for the training of special types of

hydrologists familiar with meteorology and meteorologists familiar with hydrology; this should be taken into account in planning their curricula.

Recommendations

18. In the interest of efficient use of manpower and funds, it is apparent from the foregoing discussion that hydrological and meteorological service functions should be highly coordinated, if not integrated. The required coordination becomes unwieldy, to say the least, if the two activities are in different departments or ministries. It is perhaps equally important that the control and guidance of the services rest with the national government to assure standardization to minimize geographical boundary problems, etc.

19. In an emerging country looking to water resources development with possible assistance from international governmental sources, it is perhaps relatively feasible to organize governmental services along optimum lines. The shortage of trained personnel and the need to minimize government expenditures elevate the importance of organizational efficiency are of overriding importance in such a country. In this case there can be little doubt that the best approach lies in an integrated hydrometeorological service providing basic data and forecasts. The service should be in a position to undertake research relevant to its assigned activities and to provide specialized observations, as appropriate, to other water resources development and management agencies. Its research responsibilities need not constitute a limitation on that conducted at universities and other institutions.

20. Considerable attention should be paid to training of local personnel. Special training of hydrologists in meteorology and of meteorologists in hydrology would be advisable.

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